(12) UK Patent Application (19) GB (11) 2 129 126 A

(21) Application No 8231156
(22) Date of filing 1 Nov 1982
(43) Application published 10 May 1984
(51) INT CL³ G01B 11/04 G07D 7/00
(52) Domestic classification G1A A2 C3 C4 D10 EH G14 G16 G1 G2 G9 R7 S10 T15 T20 T27 T3 T8 U1S 1577 2145 2272 G1A
(56) Documents cited GB 1383962
(58) Field of search G1A
(71) Applicant
De La Rue Systems Limited (United Kingdom), De La Rue House, 3—5 Burlington Gardens, London W1A 1DL
(72) Inventor
Ronald Sidney Pettet
(74) Agent and/or Address for Service
Gill, Jennings & Every, 43/64 Chancery Lane, London WC2A 1HN

(54) Dimension of rectangular sheets

(57) To measure the true width or length of a moving sheet, which may not be travelling with its leading edge perpendicular to the direction of motion, sensors are positioned along the feed path, two sensors being spaced in the feed direction and two sensors being spaced in a direction transverse to the feed direction. By measuring the period between signals from two sensors (e.g. S_1, S_3) spaced in the feed directions for the passage of the same edge of the sheet the velocity is obtained and by measuring the period between signals from one sensor corresponding to the passage of the leading and trailing edges of the sheet and the period between corresponding edge signals from two sensors (e.g. S_1, S_2) spaced transversely to the feed direction, the true dimension of the sheet perpendicular to its leading and trailing edges can be obtained, irrespective of skew. Folded or missing corners (Figures 2—4 not shown) can also be recognised by a four detector array.

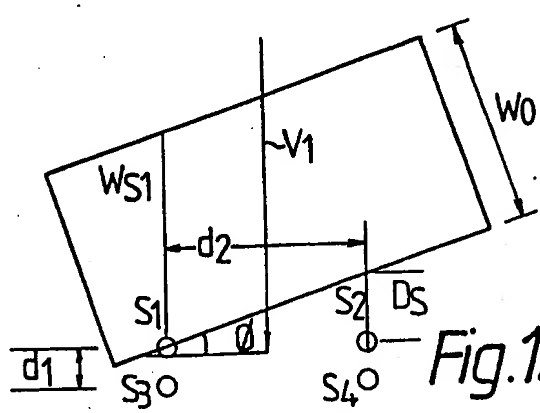

Fig.1A.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

GB 2 129 126 A

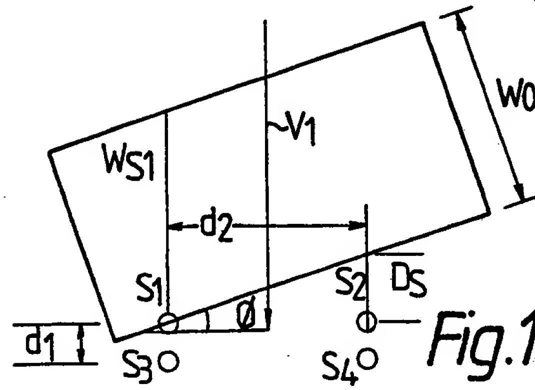

Fig.1A.

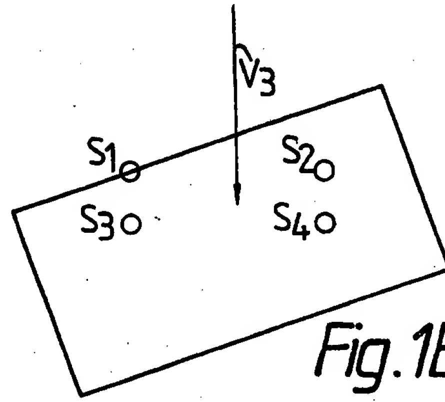

Fig.1E.

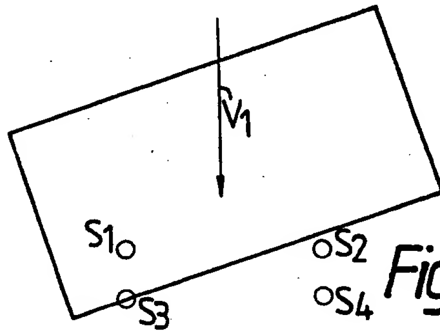

Fig.1B.

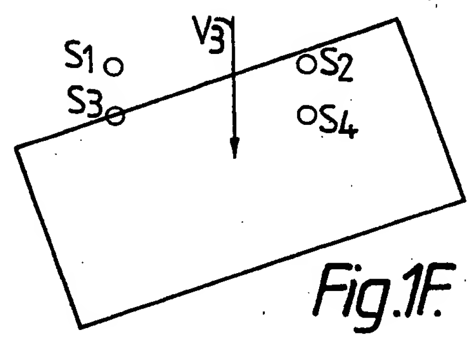

Fig.1F.

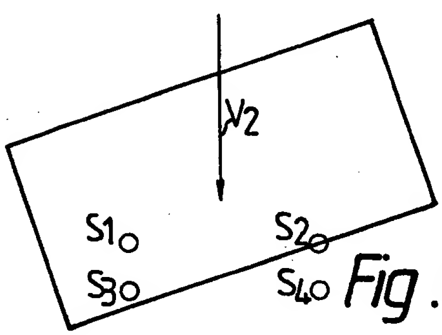

Fig .1C.

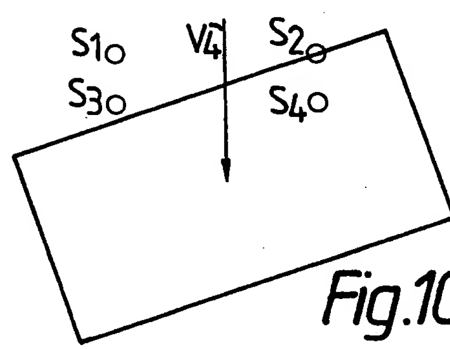

Fig.1G.

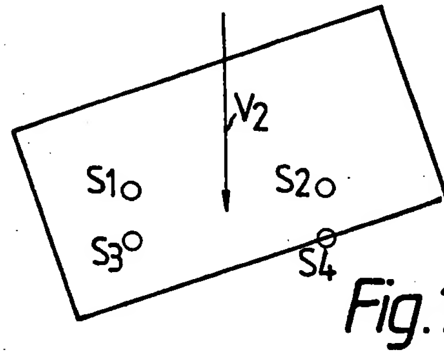

Fig.1D.

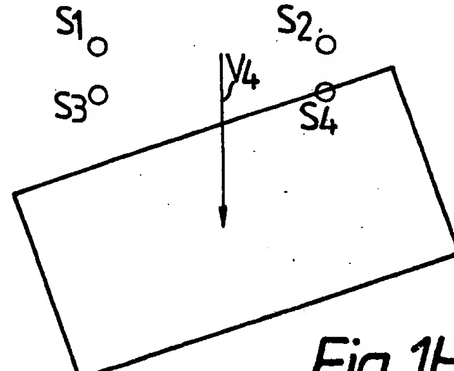

Fig.1H.

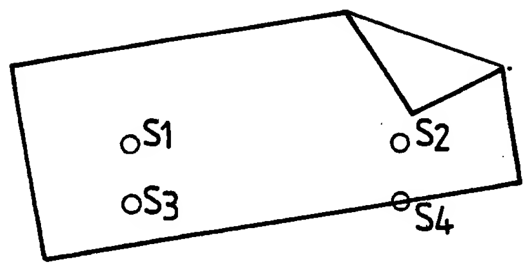

Fig.2.

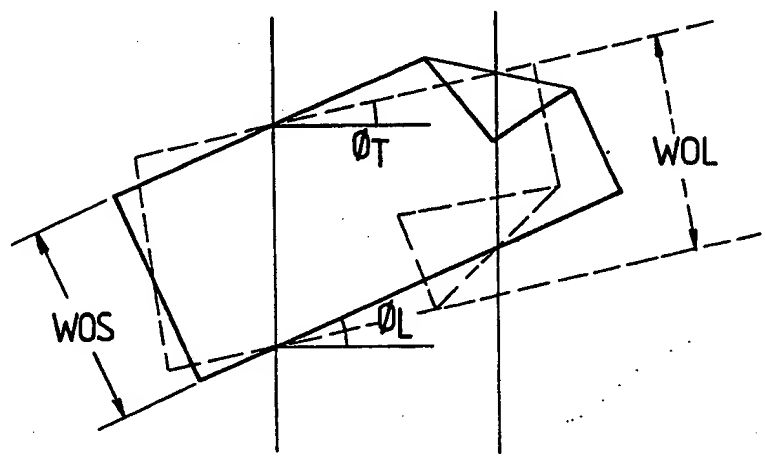

Fig.3.

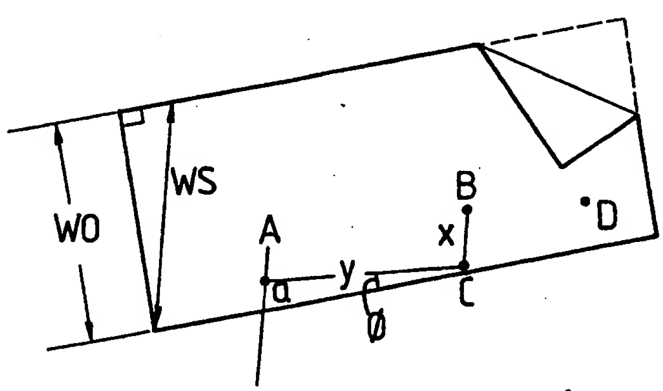

Fig.4.

SPECIFICATION

Width detection of rectangular sheets

The present invention relates to apparatus for detecting the width (or length) of a rectangular sheet such as a banknote fed along a path through the apparatus. The invention is particularly useful for discriminating between different denominations of banknote by measuring their width and for example rejecting those of less than a certain predetermined width.

Apparatus according to the present invention, for measuring the length or width of a rectangular sheet, includes sheet-feeding means for moving sheets in succession along a path through the apparatus and further comprises, for detecting the true dimension of the moving sheet in a direction perpendicular to its leading and trailing edges, irrespective of skew of the sheet in relation to the feed path direction: at least two sensors positioned along the feed path and spaced in the feed direction and at least two sensors positioned along the feed path and spaced in a direction transverse to the feed path direction; and electronic means responsive to the period between signals from one sensor corresponding to the passage of the leading and trailing edge of a sheet past that sensor, to the period between corresponding edge signals from two sensors spaced transversely to the feed direction, and to the known distances between the sensors, to provide a signal representing the true dimension of the sheet perpendicular to its leading and trailing edges irrespective of skew.

Fewer than four sensors may be employed if the sheet transport can be gauranteed to move the sheet at constant velocity and without rotation, provided that there are two sensors spaced in the feed direction and two sensors spaced in a direction transverse to the feed direction.

In the preferred form, the electronic means also responds to the period between signals from two sensors spaced in the feed direction, for the same edge, and provides a signal representing the true dimension of the sheet perpendicular to its leading and trailing edges, irrespective of the feed velocity of the sheet.

In one embodiment of the invention, four sensors are arranged at the corners of a rectangle aligned with the feed direction.

The period between the trailing edge signals from the two sensors on the left will generally be the same as between the leading edge signals from those two sensors; these periods will also be the same as the corresponding periods for the sensors on the right, but only when there is no missing or folded corner in the line of two of the sensors. The preferred apparatus calculates a skew width "seen" by each of the four sensors independently, by calculating the velocity of the sheet from the period measured between corresponding edge signals from the two sensors on one side of the sheet, and from the period measured between the leading edge signal and the trailing edge signal from the relevant sensor. If the skew widths seen by all the sensors are substantially the same, then it is assumed that there is a constant skew angle and a constant velocity. In this event, the control means computes an average value of the skew width and from this derives the true width by multiplying the skew width by a trigonometric function of the skew angle.

In the event, however, that the skew widths "seen" by the sensors do not agree, the skew angle is taken to be either that calculated from the timing of the leading edge or that calculated from the timing of ther trailing edge, past the said sensor on the left and the sensor on the right, whichever of the two angles is the larger. If the difference in skew widths is due to a folded or missing corner, this selection has the effect of selecting the measurement which is unaffected by a folded or missing corner, as will be explained later.

Also, in the event that the skew widths seen by the sensors do not agree, the control means preferably chooses the largest of the skew widths, and then calculates the true width from this largest width and the appropriate skew angle.

At least two of the sensors, one on the left and one on the right, may also respond to the degree of transmission of light through the sheet in order to detect the thickness of the sheet. This gives a further positive indication of a corner fold and allows the control means to determine whether the corner fold is on the leading or the trailing edge of the sheet.

In another arrangement of the sensors, which is particularly advantageous in providing the true measurement of the width or length of a note irrespective of folded or torn-away corners, two of the sensors are aligned and spaced apart in the feed direction and third and fourth sensors are arranged one on each side of the first two sensors, transversely to the feed direction.

The preferred apparatus is used for discriminating between different types of banknote by measuring their widths and rejecting those of less than a certain predetermined width.

In order that the invention may be better understood, a preferred embodiment will now be described with reference to the accompanying drawings, wherein:-

Figure 1 illustrates the passage of a rectangular banknote past the four sensors of the preferred apparatus;

Figure 2 shows a skewed banknote with a corner fold as it is passing the detector of Figure 1;

Figure 3 illustrates the measurement of the width of a sheet, irrespective of the presence of a folded corner on the sheet; and

Figure 4 illustrates another arrangement of sensors which is particularly advantageous in measuring the width of sheets with folded corners.

The apparatus shown schematically in the drawings is particularly useful for detecting and rejecting banknotes of denominations which have become accidentally or fraudulently mixed with a

higher denomination. It can however be used for detecting the width or length of any predominantly rectangular sheet. The four optical sensors of the preferred embodiment enable it to detect the presence of banknotes in the transport mechanism; determine speed of the banknote at different stages of its passage over the sensors; measure the angle of skew of the banknote compared with the direction of transport; measure the time difference between the arrival of the leading edge and the trailing edge of the banknote at each of the four sensors; calculate accurately using the above data the true dimension of the banknote in the intended line of flow through the transport; compare the true dimension of the banknote with a stored reference dimension, or with the corresponding dimension in other documents fed in the same sequence; and reject those banknotes that differ by more than a predetermined from either the stored reference or from each other.

The diagram of Figure 1 shows different stages of the passage of a banknote past the four sensors, the sequence being defined in the order A to H. The direction of feed is signified by the arrow, and the velocity by the symbol V1 to V4. The four optical sensors, S1 to S4, are arranged at the corners of a rectangle of dimensions d1 and d2. A suitable timing device (not shown) such as a microprocessor-controlled clock or timer is used to time the interval between the arrival of the leading and trailing edges at each of the four sensors. The microprocessor can recognise which stage, A to H, the banknote has reached by means of gating logic responsive to the various possible combinations of sensors which are obscured by the banknote. Given the timing of the arrival of the edges at the various sensors, and given the predetermined separations between the various sensors, the microprocessor then calculates the true width Wo of the banknote.

At stage A, sensor S1 on the left side of the banknote is beginning to be obscured by the banknote, and an edge signal is sent to the microprocessor signifying the arrival of the leading edge. At stage B, the leading edge has arrived at sensor S3, and the corresponding edge signal is supplied to the microprocessor. The interval between stages A and B, T_{13l} is used to give the average velocity V1 of the banknote between stage A and B; $V1 = d1 \div T_{13l}$.

At stage C, the first sensor on the right side, sensor S2, is obscured, and at stage D sensor S4 is obscured. The average velocity V2 is computed in an analogous manner; $V2 = d1 \div T_{24l}$.

At stage E, the first sensor S1 is now no longer obscured by the banknote, although the other three are still obscured. This condition is recognised, and a trailing edge signal is sent to the microprocessor accordingly. The velocity V3 and V4 are obtained in an analogous manner for the stages E to H; these stages, corresponding to the passage of the trailing edge past the sensors, still have to be detected in case one of the corners of the banknotes is folded or torn. If the period between the passage of the trailing edge past sensors S1 and S3 is equal to T_{13t}, then $V3 = d1 \div T_{13t}$. In the same way, for stages G to H, $V4 = d1 \div T_{24t}$.

The velocities V1 to V4 may differ due to the rotation of the banknote as it passes the sensors, or due to fluctuations in the speed of the transport.

The skew width Ws1 of the banknote as "seen" by sensor S1, is equal to the product of the velocity of the banknote and the period between the leading edge signal and the trailing edge signal from sensor S1. Thus $Ws1 = V1 \times T_{w1}$, where T_{w1} is equal to the period between the arrival of the leading edge and trailing edge at sensor S1. Similarly, $Ws2 = V2 \times T_{w2}$; $Ws3 = V1 \times T_{w3}$; and $Ws4 = V2 \times T_{w4}$.

If the skew widths are substantially all the same, i.e. if Ws1 = Ws2 = Ws3 = Ws4, then it can be assumed that the banknote passes the sensors at a constant velocity Va and skew angle ϕ, where Va is the average of V1, V2, V3 and V4, and ϕ is the angle between the leading and trailing edges of the document and the normal to the flow path.

The skew angle ϕ is calculated as follows. If the period between the arrival of the leading edge at sensors S1 and S2 is equal to T_{12l}, then the skew dimension Ds of stage A in Figure 1 is equal to $V1 \times T_{12l}$. Considering the right-angled triangle of which the leading edge is the hypotenuse and the line joining sensors S1 and S2 is the adjacent, it will be seen that the skew angle ϕ equals arctan $(Ds \div d2)$, where d2 is the distance between S1 and S2. In order to check this measurement, the skew angle ϕ could also be calculated by timing the passage of the leading edge past sensors S3 and S4, and by timing the passage of the trailing edge past S1 and S2, or past S3 and S4.

The true width of the document Wo, which is the separation of the leading and trailing edges perpendicular to either edge, is then calculated as $Ws \times \cos \phi$, where Ws is an average skew width obtained by averaging Ws1, Ws2, Ws3 and Ws4, or by multiplying an average of the periods Ts1 to Ts4 by the average velocity Va.

The previous calculations assumed that the skew width was substantially the same for all four calculations. If however one of the corners of the banknote is torn or folded over, this will not be so and the skew width seen by the sensors will vary. This situation is illustrated in Figure 2. With the banknote of Figure 2 the periods Ts1 and Ts3 will be equal, and the periods Ts2 and Ts4 will be equal, but the period Ts1 will be longer than the period Ts2. The banknote is apparently narrower on the right side, i.e. the side of the sensors S2 and S4. The microprocessor will recognise this situation, and will ignore the periods Ts2 and Ts4 in favour of the data from the left side. Moreover, the skew angle ϕ will be smaller using the trailing edge data than using the leading edge data, because T_{12l} and T_{34l} are greater than T_{12t} and T_{34t}. The microprocessor will also recognise this situation, and will choose the greater angle for ϕ.

As can be seen from Figure 3, it is possible to

deduce the same apparent skew angle for either a smaller document with a trailing corner fold or a larger document with a leading corner fold. As the object is to reject documents that are smaller than those required, this problem is overcome by choosing the larger value of skew angle (in this example the leading edge skew angle ϕ_L). Using this angle will cause the calculation to produce the smaller value W_{os} of the two possible values of true width. In this way the document will invariably be detected if it is smaller than the required width. Documents with leading corner folds will also be rejected, but the object has been met in so much as it "failed safe".

In the event that a larger document than required is presented with a leading corner fold it would not be rejected if the amount of skew coincided with the correct amount of corner fold to be calculated as a normal size document. However, it is unlikely that a larger document would be undetected in a bundle of smaller notes prior to machine counting and in any event the larger document would need to be exactly skewed and leading edge corner folded to given an apparent correct document. The probability of this is also very low.

In the preferred form the apparatus further comprises means for measuring the thickness of the note and this assists in discriminating against measurements falsified by folded or missing corners. Thus, at least two of the sensors, for example S1 and S2, may be connected to circuits which respond to the degree of transmission of light through the banknote, so that the resulting signal is indicative of the thickness. The microprocessor would then distinguish between single and double thicknesses of paper, and could detect the presence and the position of a corner fold.

Figure 4 illustrates a different arrangement of four sensors which is particularly advantageous in reducing the possibility of error due to corner folds. In Figure 4, the velocity V of the sheet is measured as the interval between the instants at which the same edge of the sheet passes the sensors B and C, i.e. x/t_x.

From this, the skew angle ϕ is known, since the distance $a = V.\,t_a$ and $\phi = \tan^{-1} a/y$.

The skew width W_s is then given by:-

$W_s = V/ta_t - ta_1)$ where $ta_t - ta_1$ is the time difference between leading and trailing edges passing sensor A. Therefore, the true width W_o is given by:-

$$W_o = V\,(ta_t - ta_1)\,\mathrm{Cos}\,\phi = V\,(ta_t - ta_1)\,\mathrm{Cos}\left(\tan^{-1}\frac{V.ta}{y}\right)$$

If the time interval for the passage of the leading edge past the sensors A and C is substantially the same as the time interval for the passage of the same edge past sensors B and D, and if the same applies to the passage of the trailing edge past the sensors, then there are no significant corner folds. If on the other hand the two intervals are equal for the leading edge but unequal for the trailing edge, then a corner fold exists at the trailing edge. Similarly if there is an inequality at the leading edge, there is a leading edge corner fold.

The apparatus of this preferred embodiment is intended to be incorporated in banknote discriminating apparatus which diverts banknotes to a reject bin if their true width is less than a predetermined width corresponding to a reference dimension or to the corresponding dimension in other documents fed in the same sequence.

CLAIMS

1. Apparatus for measuring the length or width of a rectangular sheet including sheet-feeding means for moving sheets in succession along a path through the apparatus and comprising, for detecting the true dimension of the moving sheet in a direction perpendicular to its leading and trailing edges, irrespective of skew of the sheet in relation to the feed path direction: at least two sensors positioned along the feed path and spaced in the feed direction and at least two sensors positioned along the feed path and spaced in a direction transverse to the feed path direction; and electronic means responsive to the period between signals from one sensor corresponding to the passage of the leading and trailing edges of a sheet past that sensor, to the period between corresponding edge signals from two sensors spaced transversely to the feed direction, and to the known distances between the sensors, to provide a signal representing the true dimension of the sheet perpendicular to its leading and trailing edges irrespective of skew.

2. Apparatus in accordance with claim 1, in which the electronic means is also responsive to the period between signals from two sensors spaced in the feed direction, and corresponding to the same edge, and is operative to provide a signal representing the true dimension of the sheet perpendicular to its leading and trailing edges, irrespective of the feed velocity of the sheet.

3. Apparatus in accordance with claim 1 or 2, comprising first and second pairs of sensors on opposite sides of the middle of the feed path, the two sensors of each pair being spaced in the feed direction.

4. Apparatus in accordance with claim 1 or 2, comprising first and second sensors aligned and spaced in the feed direction substantially in the middle of the feed path, and third and fourth sensors arranged on each side of the first and second sensors.

5. Apparatus in accordance with claim 4, wherein the third sensor is on a line perpendicular to the feed path and passing through the first sensor and the fourth sensor is on a line perpendicular to the feed path and passing through the second sensor.

6. Apparatus in accordance with claim 3, wherein the electronic means computes the angle of skew of the leading and/or trailing edges of the

sheet with respect to the normal to the feed direction, as a function of (a) period between corresponding edge signals from a sensor on the left and a sensor on the right, (b) the period between corresponding edge signals from the two sensors on one side of the sheet, which period depends on the velocity of feed, and (c) the constant distance between the sensor on the left and the sensor on the right referred to in (a) above.

7. Apparatus in accordance with claim 6, wherein the electronic means calculates a skew width "seen" by each of the four sensors independently, by calculating the velocity of the sheet from the period measured between corresponding edge signals from the two sensors on one side of the sheet, and from the period measured between the leading edge signal and the trailing edge signal from the relevant sensor.

8. Apparatus in accordance with claim 7, wherein the electronic means, in the event that the skew widths "seen" by the sensors do not agree, derives a skew angle which is either that calculated from the timing of the leading edge or that calculated from the timing of the trailing edge, past the sensor on the left and the sensor on the right, whichever of the two angles is the larger.

9. Apparatus in accordance with claim 5, wherein the electronic means computes the angle of skew of the leading and/or trailing edges of the sheet with respect to the normal to the feed direction, as a function of (a) the period between corresponding edge signals from the first or second sensor and the third or fourth sensor, (b) the period between corresponding edge signals from the first and second sensors, which period depends on the velocity of feed, and (c) the constant distances between the first and second sensors and between these sensors and the third or fourth sensors.

10. Apparatus in accordance with claim 9, wherein the electronic means further computes the true width of the sheet as a function of (a) the skew angle, (b) the period between corresponding edge signals from the first and second sensors, (c) the constant distance between the first and second sensors, and (d) the period between the leading and the trailing edge signals from either the third or the fourth sensors.

11. Apparatus in accordance with any preceding claim, including means for illuminating the sheets from one side, the sensors being arranged on the other side of the sheet path so that each sensor provides an edge signal at the instant it becomes obscured by the sheet and at the instant it is uncovered by the sheet.

12. Apparatus in accordance with any preceding claim, wherein at least two sensors on opposite sides of the middle of the feed path are connected to circuits which respond to the degree of transmission of light through the sheet in order to detect the thickness of the sheet, thereby giving to the electronic means a positive indication of a corner fold.

13. Apparatus for determining the width or length of a rectangular sheet substantially as herein described with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1984. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.